high-risk investment with very little profit incentive in the short term. These factors lead to one clear conclusion: the federal government, specifically the Department of Energy, must lead the way if the U.S. is to complete its energy sustainability puzzle.

The Department of Energy's Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), and the National Energy Technology Laboratory (NETL) are already collaborating to plan an integrated energy-water R&D program. The three laboratories possess the requisite expertise in science and technology to lead the initiative, but perhaps even more important are their proven abilities to successfully manage complex, multidisciplinary programs in collaboration with industry, academia, and government agencies.

Completing the Puzzle

Electricity and water are at the heart of the U.S. economy and way of life. National defense, food production, human health, manufacturing, recreation, tourism, and the daily functioning of households all rely on a clean and affordable supply of one or both of them.Understanding the complex relationship between water and electricity and developing technologies to keep that relationship healthy is an important key to a sustainable and secure future for the United States.

National Benefits

A national research, development, and demonstration program focused on the interrelationships between water and energy would bolster U.S. energy sustainability by

- **creating a detailed source of water/energy information to aid policy-makers;**
- **providing well-targeted technological solutions;**
- **ensuring a stable water resource for energy producers;**
- **reducing the energy cost of providing clean, affordable water;**
- **improving the quality of the nation's fresh water supplies; and**
- **alleviating competition between energy producers and other water users.**

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Sandia National Laboratories

NETL

Los Alamos NATIONAL LABORATORY

U.S. Energy Sustainability
The Missing Piece

U.S. energy sustainability is a complex puzzle of interlocking parts. Federally supported research and development (R&D) is being carried out to address key pieces of this puzzle including advanced fossil and nuclear energy technologies, energy efficiency, infrastructure systems, pollution control and prevention, and renewable and alternative energy. However, one critical component of the R&D mix is missing—water. Currently, there is no national research program directed specifically at understanding the intimate relationship between energy and water.

The Energy—Water Connection

Energy production requires a reliable, abundant, and predictable source of water, a resource that is already in short supply throughout much of the U.S. and the world. The electricity industry is second only to agriculture as the largest user of water in the United States. Electricity production from fossil fuels and nuclear energy requires 190,000 million gallons of water per day, accounting for 39% of all freshwater withdrawals in the nation, with 71% of that going to fossil-fuel electricity generation alone.[1] Coal, the most abundant fossil fuel, currently accounts for 52% of U.S. electricity generation, and each kWh generated from coal requires 3.3 gallons of water. That means U.S. citizens may indirectly depend upon as much water turning on the lights and running appliances as they directly use taking showers and watering lawns. According to the Bush administration's 2001 *National Energy Policy*, our growing population and economy will require 393,000 MW of new generating capacity (or 1,300 to 1,900 new power plants—more than one built each week) by the year 2020, putting further strain on the nation's water resources.

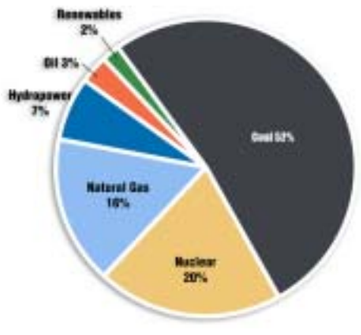
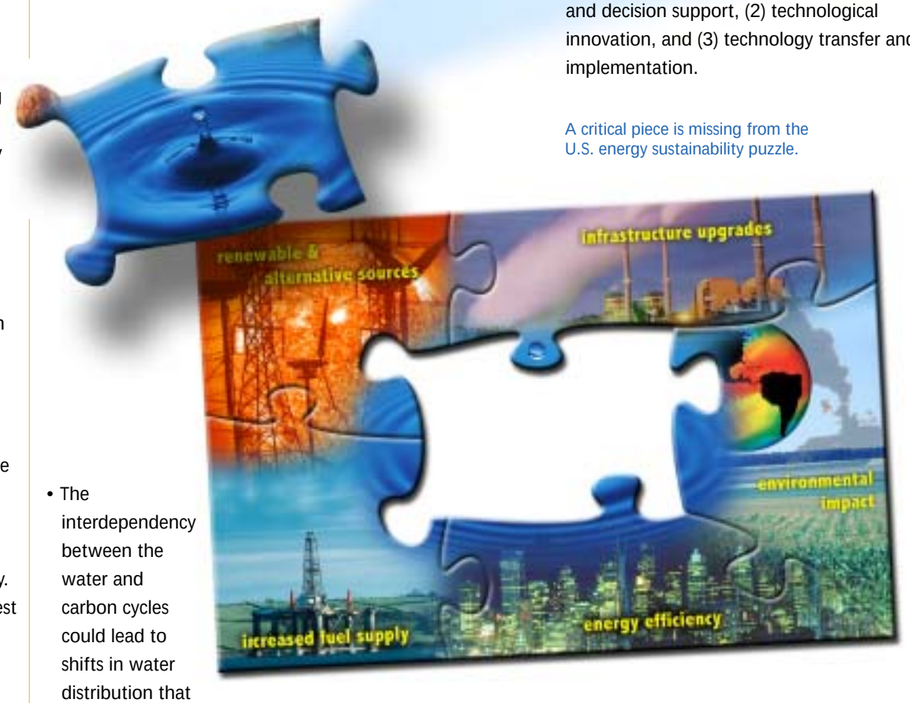


Figure 1: Fuel sources for electricity generation. Coal and nuclear energy account for 72% of U.S. electricity generation and together account for more than a third of all freshwater withdrawals (chart from *National Energy Policy,* 2001).

Several related factors bring into question whether a stable, affordable supply of water will exist to support the nation's future electricity demands:

- While U.S. population is expected to rise significantly, accessible freshwater supplies are not. Moreover, population movement and energy demand do not always track well with water availability. During the 1990's in the U.S., the largest regional population growth (25%) occurred in one of the most water deficient regions, the mountain west. Water availability is also becoming a serious issue in the southeast, where population has increased by nearly 14% since 1990. By comparison, the water-rich northeast has experienced only a 2% growth in population.[2]
- An increasing population will not only need more electricity but also more food, pushing the nation's two largest water users into potential competition for limited water resources.
- Proposed restrictions on the use of water for power generation to protect fish and other aquatic organisms could result in increased costs of electricity or potential energy shortages.
- Because the energy required for treatment and delivery of water accounts for as much as 80% of its cost, an insufficient supply of affordable energy will have a negative impact on the price and availability of water.



A critical piece is missing from the U.S. energy sustainability puzzle.

- The interdependency between the water and carbon cycles could lead to shifts in water distribution that are difficult to predict. That is, increases in electricity production and use may lead to higher levels of atmospheric carbon, which can impact the availability of water to electricity producers in certain regions.

In summary, the intimate link between clean, affordable energy and clean, affordable water is crystal clear. There cannot be one without the other.

Future National Needs

To sustain energy production, the United States must gain a detailed understanding of the interdependencies of water-reliant systems, balance the needs of all users, and develop technologies to reduce water use and loss. These goals can be achieved through a focused research and development program that integrates the following three components: (1) prediction and decision support, (2) technological innovation, and (3) technology transfer and implementation.

Key RD&D components of the energy-water initiative.

Prediction and Decision Support

This component of the program would focus on creating a suite of decision tools to predict energy impacts on water quality and quantity, forecast water and energy supply and demand on a regional basis, and identify trouble spots by analyzing "what if" scenarios. These tools would be based on high-performance computer models that link the many systems and forces that influence water and energy resources, such as climate change, land-use change, regional hydrological cycles, population growth and movement, energy use, infrastructures, and regulatory and market forces. These linkages would provide an unprecedented level of accuracy and allow decision makers to optimize the balance of water usage among stakeholders. Such predictive tools would be invaluable in guiding technology investments, predicting impacts of policy and regulatory decisions, and aiding economic development plans.

Technological Innovation

The technology component of the proposed research program would focus on minimizing the impact of energy production on water quality and availability and reducing the amount of energy required for treating and distributing water.

Technological innovations could be directed at (1) treating and reusing non-potable process ("gray") water in power production; (2) accessing currently unused water sources, such as saline aquifers; (3) reducing or eliminating water use altogether in generating power; (4) delivering water and energy more efficiently to prevent losses; and (5) minimizing water-related impacts from mining, energy production and use, and disposal of solid byproducts. Since power plant cooling consumes the largest amount of water and current cooling technologies have associated environmental penalties, one potential avenue of research might be to develop innovative, affordable cooling systems that would reduce or eliminate the need to use water. Another might be to tap into deep, saline aquifers or flooded underground mine workings for plant cooling and return the water back to the deep aquifer or mine in a closed-loop cycle.

Research could also be directed at reducing the energy required to treat, pump, and distribute water, including improvements in wastewater treatment processes and irrigation technology.

Implementation and Technology Transfer

One key to the program's success will be the early formation of stakeholder teams that can provide real-world feedback, test the decision support systems, prototype technological innovations, and implement solutions quickly. These teams will include national laboratories and universities that conduct research and development; state and federal agencies responsible for water, energy, and environmental management; and industries and consortia involved in the production and/or distribution of water and energy.

Leading the Way

Water is an energy issue, and both water and energy are issues of national security. Ensuring our water and energy supply will require multidisciplinary scientific and technical expertise and involve long-term,

[1] U.S. Geological Survey. *Estimated Use of Water in the United States in 1995.* http://water.usgs.gov/watuse/pdf1995/html/

[2] U.S. Census Bureau. Population Estimates Program, Population Division.